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Global warming and environmental benefits of hydroelectric for sustainable energy in Turkey

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ABSTRACT

Over the last two decades; technical, economic and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries. Turkey has a total gross hydropower potential of 433 GWh/yr, but only 125 GWh/yr of the total hydroelectric potential of Turkey can be economically used. By the commissioning of new hydropower plants, which are under construction, 36% of the economically usable potential of the country would be tapped. Turkey's total economically usable small hydropower potential is 3.75 GWh/yr. It is expected that the demand for electric energy in Turkey will be about 580 billion kWh by the year 2020. Turkey is heavily dependent on expensive imported energy sources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Environmentally friendly energy development has enormous implications for developing countries as major emitters due to their rapid economic and population growth. With some possible options, the paper concludes that the reduction of emissions can only be achieved when policies are supportive and well targeted, standards and incentives are realistic and flexible, and the public is actively responsive to environmental degradation. Turkey's high rate of energy-related carbon emissions growth is expected to accelerate, with emissions climbing from 57 million tons in 2000 to almost 210 million tons in 2020. Carbon intensity in Turkey is higher than the western developed nation average. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. This paper deals with Turkey's renewables energy sources for sustainable environment.

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Contents

1. Introduction

More generally, global warming and climate change and sustainable development interact in a circular fashion. Climate change vulnerability, impacts and adaptation will influence prospects for sustainable development, and in turn, alternative development

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paths will not only determine greenhouse gas (GHG) emission levels that affect future climate change, but also influence future capacity to adapt and mitigate climate change. Impacts of climate change are exacerbated by development status, adversely affecting especially the poor and vulnerable socio-economic groups. The capacity to adapt of climate change goes beyond wealth, to other key pre-requisites of good development planning, including institutions, governance, economic management and technology [1–3].

Global warming and climate change poses an unprecedented threat to all human beings. While this problem is important in the long-run, most decision-makers recognize (especially in the developing countries), that there are many other critical sustainable development issues that affect human welfare more immediately. However, even in the short term, climate is an essential resource for development. For example, in many countries (especially the poorest ones), existing levels of climatic variability and extreme events pose significant risks for agriculture, economic infrastructure, and vulnerable households. Climatic hazards continue to take their human and economic toll even in wealthy countries. Such climate threats, which undermine development prospects today, need to be better addressed in the context of the long-run evolution of local and regional climates [2–4].

Delivering sustainability demands that this access and security of supply be provided, while avoiding environmental impacts, which would compromise future social and economic development. Drawing on the wide-ranging discussions of the Congress, the World Energy Council draws some conclusions as follows [3,5,6].

Climate change is a serious global concern, calling for changes in consumer behavior, but offering potential win–win opportunities. These include increased transfer of efficient technologies from industrialized to developing countries and incentives to investment through emerging voluntary and regulated emissions trading [3].

Technological innovation and development is vital to reconciling expanded energy services for more equitable economic development with protection of the environment. Research and development (R&D) must be more strongly and consistently supported than has been the case. It is the pre-condition of the innovation which is needed. A starting point is the reduction of R&D redundancies through international cooperation [3].

However, developing the remaining hydropower potential offers many challenges and pressures from some environmental action groups over its impact has tended to increase over time. Hydropower throughout the world provides 17% of our electricity from an installed capacity of some 730 GW is currently under construction, making hydropower by far the most important renewable energy for electrical power production. The contribution of hydropower, especially small hydropower (SHP) to the worldwide electrical capacity is more of a similar scale to the other renewable energy sources (1–2% of total capacity), amounting to about 47 GW (53%) of this capacity is in developing countries [3,6,7].

All energy options must be kept open and no technology should be idolized. These include the conventional options of coal, oil gas, nuclear, hydropower and the new renewable energy sources, combined of course with increased energy efficiency. A larger share of global infrastructure investment must be devoted to energy. For this cost-reflective prices are essential. Energy systems, which do not pay for themselves over the medium and long time period are not sustainable. A more pragmatic approach to market reform is emerging. It is now widely recognized that market interventions may be needed to achieve essential goals, including energy access, security of supply, the promotion of innovation and a level playing field in which external environmental impacts are reflected in prices.

The reliability of electricity supply is an important priority. In industrialized countries, consumers demand 100% reliability, while those in developing countries often suffer frequent disruptions. The cost burden of these disruptions has already been noted. Regional integration of energy supply systems can boost access and energy supply security. Regional collaboration needs to be enhanced to harmonize energy regulation and create the necessary infrastructure. It is also a key to optimizing the water-energy nexus.

Energy is essential to economic and social development and improved quality of life in all countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. On the other hand the need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country. Electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and also sustaining economic growth [8].

2. Global warming in Turkey

When the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992, all OECD members were included in the list of developed countries in Annex II. Turkey asked for an exception on the grounds that its relative underdevelopment from other OECD members justified special treatment. Such an exception was granted at the Seventh Conference of Parties in Marrakech in 2001, where Turkey was removed from the Annex II. Consequently, the parliament is expected to ratify the Convention. This exception is notable because the flexible implementation mechanisms of the Kyoto Protocol (assuming eventual ratification by Turkey) will open up new avenues for foreign investments for energy efficiency and clean technology projects [3,9,10].

Following the ratification of the Framework Convention and the Kyoto Protocol, Turkey has become eligible for trade in carbon credits under the provisions of the Clean Development Mechanism. While the necessary institutional capacities and information systems remain to be developed, the government declared its willingness to comply with the general provisions of the UNFCCC. Unlike domestic energy procurement strategies, the global warming dimension of energy politics receives scant attention from civil society and environmental NGOs. Nevertheless, international pressure, especially through the European Union, is likely to lead Turkey to take real steps toward helping prevent global warming [3,10–12].

Toward this end, the preparation of the 8th Five-Year Development Plan included for the first time an Expert Committee on Climate Change. The committee's recommendations lean heavily toward market-based solutions, support the recent trend toward increased natural gas consumption and make a number of commonsensical suggestions [3,10,13]. A number of promising steps have been taken toward the implementation of these policies. The Electricity Market Act and the Natural Gas Market Law, both of 2001, increased competition and further private involvement. However, given the projected increase in energy demand and consumption, any meaningful reduction of future greenhouse gases in Turkey will necessitate significant investment in renewable energies beyond the current interest in hydropower.

Energy development in Turkey has been dominated by public investment and management. The current government, however, is keen to complete the process of liberalization, restructuring, and privatization in the energy sector. Turkey has made early and extensive use of financing models such as build-own-operate (BOO) and build-own-transfer (BOT). As yet, however, no decisive

breakthrough has been achieved. This does not mean a complete withdrawal of the state from energy development. In fact, state involvement in formulating and implementing favorable policies for renewable energy development remains vital. To ensure timely and effective investment in renewable sources, however, the state needs to mobilize the extensive funds available to the private sector. A number of renewable energy projects, such as certain hydropower and solar thermal applications, are already commercially attractive to private interests [3].

However, more often than not, they are placed in a dilemma when left to balance between economic growth and environment. Conflicts often rise between social, environmental and economic objectives [3,13,14]. The headlong pursuit of economic growth is the cornerstone of developing countries. A top Turkish environmental official accepted that economic growth must take precedence over environmental protection for years to come because the former is not only of great importance to maintaining political stability but also to funding the environmental clean-up [2,3].

Since possible results of the global warmth gradually started to form the most basic problem on environmental basis, “Framework Convention on Climate Changes” (FCCC) is constituted which was due on March 21, 1994 followed by its approval by 50 countries after being first approved in Rio Environment and Development Conference held in 1992. Aim of the Convention is to keep the concentration of greenhouse gas in the atmosphere at a constant level necessary to prevent its hazardous man caused impact on climate system. On the other hand, international society will come to a common decision in Conference of Parties (COP) held annually where all participating countries are closely involved in decision making process [2,3,15].

3. Climate change in Turkey

Sustainable development has been recognized as a key cross-cutting theme in the preparation of the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. Researchers could make pivotal contributions to the IPCC's work on sustainable development, with contributions to this volume highlighting some of the key issues requiring investigation and analysis. On the other hand, technologies and practices to reduce GHG emissions are continuously being developed. Many of these technologies focus on improving the efficiency of fossil fuel energy or electricity use and the development of low carbon energy sources, since the majority of GHG emissions are related to the use of energy. Energy intensity (energy consumed divided by gross domestic product, GDP) and carbon intensity (CO_2 emitted from burning fossil fuels divided by the amount of energy produced) have been declining for more than 100 years in developed countries without explicit government policies for decarbonization, and have the potential to decline further [2,3,16].

Perhaps the most contentious issue is the conceptual framework for addressing climate change within a sustainable development mandate. Various stakeholders are bound to have different views and analytical frameworks to support their positions. Given the extent to which the respective debates on climate change and sustainable development have evolved separately in the past, it will be a significant challenge to re-integrate climate change with development policy [2,3,17]. Existing scenarios are seldom probabilistic and socio-economic projections tend to be static world-views with little correspondence to the punctuated, dynamic, event-response nature of reality. For example, few vulnerability/adaptation researchers consider scenarios of GHG emissions projections as adequate for understanding potential failures of climate policy [3].

Table 1
Emission mitigation potential in Turkey.

Privatizing energy resource production.
Increasing the share of natural gas in consumption.
Transferring electricity production and distribution to the private sector to make utility services more efficient.
Encourage power savings by matching costs to prices and preventing theft.
Developing new and renewable energy sources and ensuring their greater role in the market.
Converting railway management to commercial orientation to ensure efficient, market oriented services.
Investing in natural gas pipelines and storage facilities.
A comprehensive strategy is needed for developing renewable energy sources offshore and this should cover assessment of environmental impacts.
Combining heat and power plants should be regarded primarily as a source of heat.
Increasing energy efficiency and ensuring energy savings.
Improving the petroleum product quality for cut sulfur emissions.
Using proper energy management model for the future of Turkey.

Source: Refs. [3,18].

Turkey's most recent Five-Year Development Plan, adopted in 2000, affects all policies in all economic sectors and has an indirect impact on GHG emissions. The first Special Expert Committee on Climate Change was established as one of 98 consultative committees during preparation of this plan. The committee's recommendations were published by the Turkish prime minister as official policy for the current planning period. Table 1 shows the emission mitigation potential in Turkey [3].

These recommendations serve to guide government actions, but their actual implementation depends on the actions of various agencies and regulators. Under the Electricity Market Act adopted in 2001, the power sector will soon undergo profound reform, leading to the introduction of competition and increasing private involvement. The Turkish Council of Ministers has adopted several measures to stabilize fuel prices. An automatic pricing formula was abolished and gasoline taxes were made consistent with European countries. For example, taxes comprised over 60% of the price of gasoline by late 2000. To increase energy efficiency in industrial sectors, energy conservation regulations were issued in 1995. These required industrial establishments with annual consumption above 84 terajoules to establish an internal energy management system, conduct energy audits and appoint an energy manager in their plants [2,3,19].

According to recent projections, total primary energy supply (TPES) will almost double between 2006 and 2020, with coal accounting for an increasingly important share, rising from 24% in 2006 to 36% in 2020, principally replacing oil, which is expected to drop from 40% to 27%. Such trends will lead to a significant rise in CO_2 emissions, which are projected to reach nearly 600 Mt in 2020, over three times 2004 levels [3,6,20–22].

In 2006, public electricity and heat production were the largest contributors of CO_2 emissions, accounting for 30% of the country's total. The industry sector was the second largest, representing 28% of total emissions, followed by transport, which represented 20% and direct fossil fuel use in the residential sector with 8%. Other sectors, including other energy industries, account for 14% of total emissions. Since 1990, emissions from public electricity and heat production have grown more rapidly than in other sectors, increasing by 6%. Simultaneously, the shares of emissions from the residential and transport sectors both dropped by 7% and 3% respectively while the share of emissions from the manufacturing industries and construction sector remained stable [3,6,12,22–24].

Turkey was a member of the OECD when the UNFCCC was adopted in 1992, and was therefore included among the so-called Annex I and Annex II countries. Under the convention, Annex I countries have to take steps to reduce emissions and Annex II countries have to take steps to provide financial and technical assistance

to developing countries. However, in comparison to other countries included in these annexes, Turkey was at a relatively early stage of industrialization and had a lower level of economic development as well as a lower means to assist developing countries. Turkey was not given a quantified emissions reduction or limitation objective in the Kyoto Protocol. Following a number of negotiations, in 2001 Turkey was finally removed from the list of Annex II countries but remained on the list of Annex I countries with an accompanying footnote specifying that Turkey should enjoy favorable conditions considering differentiated responsibilities. This led to an official acceptance of the UNFCCC by the Turkish Grand National Assembly in October 2003, followed by its enactment in May 2004. Turkey has not yet signed the Kyoto Protocol [6,12,19,22,25].

Throughout this process, the government carried out a number of studies on the implications of climate change and its mitigation. The first efforts were undertaken by the National Climate Coordination Group in preparation for the 1992 Rio Earth Summit. Following this, a National Climate Program was developed in the scope of the UNFCCC. In 1999, a specialized Commission on Climate Change was established by DPT in preparation of the Eighth Five-Year Development Plan (2001–2005). The Five-Year Development Plan was the first planning document to contain proposals for national policies and measures to reduce GHG emissions, and funding for climate-friendly technologies [6,26].

Following the ratification of the UNFCCC, a number of working groups were set up with the objective to define a climate change mitigation strategy and compile the country's first national communication to the UNFCCC. These included a working group on mitigation in the energy sector and a working group on mitigation in the transport sector. However, it remains unclear as to when the strategy and national communication will be completed. The strategy aims to reduce GHG emissions through the implementation of appropriate measures and the development of climate-friendly technologies. Energy efficiency and the development of renewable energy sources are two important components of the strategy. However, the strategy will not include any policies that directly target GHG emissions, such as carbon taxation or emissions trading. It also does not include a specific target for emissions reductions [6,22].

4. CO_2 emission in Turkey

Turkey has achieved decoupling of SO_x, NO_x and CO_2 emissions from economic growth. In 2005, estimated SO_2 emissions are 1.9 million tons, increased by 6% between 1998 and 2005, while GDP and fuel consumption increased by 26 and 23% respectively. SO_x emission intensity (per unit of GDP) fell by 16% between 1998 and 2005. In this period, however SO_x emission intensity was over three times higher than the OECD average. Major contributors to SO_x emissions were continued for power plants (66.3%) and industrial combustion (26.1%) [27–30].

Turkey's total carbon dioxide (CO_2) emissions amounted to 239.74 million tones (Mt) in 2006 (Table 2) [22]. Emissions grew by 5% compared to 2001 levels and by just over 50% compared to 1990 levels. Oil has historically been the most important source of emissions, followed by coal and gas. Oil represented 45% of total emissions in 2004, while coal represented 40% and gas 15%. The contribution of each fuel has however changed significantly owing to the increasingly important role of gas in the country's fuel mix starting from the mid-1980s [6,12,21].

Turkey's high rate of energy-related carbon emissions growth is expected to accelerate, with emissions climbing from 57 million tons in 2000 to almost 210 million tons in 2020. Carbon intensity in Turkey is higher than the western developed nation average. Energy-intensive, inefficient industries remain under government control with soft budged constraints, contributing to undisciplined energy use in Turkey [2].

5. Air quality and air pollution in Turkey

Trends in reducing annual average concentrations of SO_2 and particulate matter (PM) in cities showed overall progress between 2002 and 2008. In Turkey, in some cities such as Ankara, Gaziantep, Izmit, Samsun, Sivas and Diyarbakir pollutant concentrations decreased, particularly during winter seasons, in some cities from levels over 260 $\mu g/m^3$ [29].

Historically, air pollution monitoring in urban areas has been performed by the Ministry of Health. Recently responsibilities have shifted to the Ministry of Environment and Forestry (MEF) and the monitoring network has expanded, benefiting from the efforts of provincial environmental departments and of universities. In 2006, 200 semi-automatic measurement stations monitored SO_2 and PM concentrations in 80 provinces. Today, all the provinces have at least one automatic measurement station for SO_2 and PM_{10}, part of the national Air Quality Monitoring Network. In addition, mobile air quality monitoring vehicles have been introduced. A national reference laboratory (under MEF coordination) is in the process of accreditation with support from the Marmara Research Center.

The main air pollutants related to the production and use of energy are CO, CO_2, CH_4, SO_2, NO_x and suspended particulates in Turkey. These emissions come mostly from the combustion of solid and liquid fuels. The use of high-sulfur lignite in particular is an important source of air pollution. As a consequence of efforts to move away from high-sulfur lignite to either imported coal or gas, air pollution concentration levels have reduced significantly in most large cities since the early 1990s. Fig. 1 shows CO_2 emissions between 1995 and 2025 in Turkey [6,31].

Table 2
Key sources for CO_2 emissions from fuel combustion for Turkey in 2006.

IPCC source category	CO_2 emissions (Mt of CO_2)	Level assessment (%)	Cumulative total (%)
Production electricity and heat-coal/peat	42.32	12.6	12.6
Manufacturing industries-coal/peat	42.30	12.6	25.1
Road-oil	36.60	10.9	36.0
Production electricity and heat-gas	27.28	8.1	44.1
Residential-gas	14.45	4.3	48.4
Manufacturing industries-oil	12.35	3.7	52.0
Residential-coal/peat	10.10	3.0	55.0
Non-specified other sectors-oil	9.69	2.9	57.9
Manufacturing industries-gas	8.01	2.4	60.3
Non-specified other sectors-gas	6.51	1.9	62.2
Other transport-oil	5.36	1.6	63.8
Total CO_2 from fuel combustion	239.74	71.1	71.1

Source: Ref. [22].

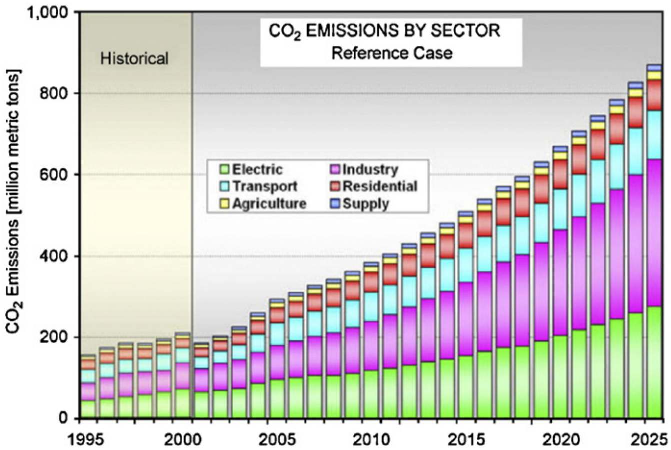


Fig. 1. Reference case CO_2 emissions between 1995 and 2025 in Turkey. *Source*: Refs. [6,31].

On the other hand, concentration levels in smaller cities where gas distribution networks have not yet been built are higher than in larger cities. In addition to this, even in cities where average air quality has improved, air quality mapping reveals that high concentration hot spots exist around heavily used roads, particularly to the west of the country, owing to higher vehicle-ownership density [6,20,23,26].

In the last ten years, Turkey emitted a total of 2.10 Mt of SO_2, equivalent to 30.4 kg per capita. This is slightly below the OECD average, which at the end of the 1990s was 32.9 kg per capita. In terms of emissions per unit of GDP, Turkey emitted 5.5 kg per US$ 1100 in 2002, among the highest levels in OECD countries where the average was approximately 1.5 kg per US$ 1000. Electricity generation and industry are by far the largest contributors to SO_2 emissions in the country, representing respectively 65% and 21% of total emissions in 2001 [6,12,22].

6. Renewables energy sources in Turkey

Renewables accounted for 12.89% of the world's total primary energy supply in 2006. However, almost 80% of the renewable energy supply was from biomass, and in developing countries it is mostly converted by traditional open combustion which is very inefficient. Because of its inefficient use, biomass resources presently supply only about 20% of what they could if converted by modern, more efficient, available technologies. The total share of all renewables for electricity production in 2003 was about 17.6%, a vast majority (90.3%) of it being from hydroelectric power [32].

Renewable energy supply in Turkey is dominated by hydropower and biomass [9,20], but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2004, due to a decrease in biomass supply [20]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources. Table 3 shows renewable energy production in Turkey [9,20,33].

Total gross hydropower potential and total energy production capacity of Turkey are nearly 50 GW and 112 TWh/yr, respectively and about 30% of the total gross potential may be economically exploitable. At present, only about 35% of the total hydroelectric power potential is in operation [34]. The national development plan aims to harvest all of the hydroelectric potential by 2010. The contribution of small hydroelectric plants to total electricity generation is estimated to be 5–10% [35,36]. On the other hand, the Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3.0 million ha of agricultural land. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tıgris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated and irrigating 1.7 million hectares [37].

Among the renewable energy sources, biomass is important because its share of total energy consumption is still high in Turkey [38,39]. Since 1980, the contribution of the biomass resources in the total energy consumption dropped from 20 to 8% in 2005 [40]. Biomass in the forms of fuel wood and animal wastes is the main fuel for heating and cooking in many urban and rural areas [38,39]. The total recoverable bioenergy potential is estimated to be about 35.4 Mtoe in 2003 [38]. On the other hand, using vegetable oils as fuel alternatives has economic, environmental, and energy benefits for Turkey. Vegetable oils have heat contents approximately 90% of that of diesel fuel. The overall evaluation of the results indicated that these oils and biodiesel can be proposed as possible candidates for fuel. Organic wastes are of vital importance for the soil, but in Turkey most of these organic wastes are used as fuel through direct combustion. Animal wastes are mixed with straw to increase the calorific value, and are then dried for use [20,24,33].

Biogas systems are considered to be strong alternatives to the traditional space heating systems (stoves) in rural Turkey [20]. The economic of biogas systems are compared with traditional heating systems fuelled by wood, coal and wood mixture and dried animal waste in three different climatic regions in the country. The technical data used in the analysis are based on the experimental

Table 3
Developments in production and consumption of energy between 2000 and 2005 in Turkey.

	2000	2001	2002	2003	2004	2005
Primary energy production (TTOE)	27,621	26,159	24,884	23,779	24,170	28,020
Primary energy consumption (TTOE)	81,193	75,883	78,322	83,936	87,778	94,300
Consumption per capita (KOE)	1204	1111	1131	1196	1234	1249
Electricity installed capacity (MW)	27,264	28,332	31,846	35,587	36,824	39,596
Thermal (MW)	16,070	16,640	19,586	22,990	24,160	26,481
Hydraulic (MW)	11,194	11,692	12,260	12,597	12,664	13,115
Electricity production (GWh)	124,922	122,725	129,400	140,580	150,698	165,346
Thermal (GWh)	94,011	98,653	95,668	105,190	104,556	124,321
Hydraulic (GWh)	30,912	24,072	33,732	35,390	46,142	41,025
Electricity import (GWh)	3786	4579	3588	1158	464	636
Electricity export (GWh)	413	433	435	587	1144	1812
Total Consumption (GWh)	128,295	126,872	132,553	141,151	150,018	
Consumption per capita (kWh)	1903	1857	1914	2011	2109	2240

Source: Refs. [3,21,24,45].

results. Seven different comparisons are made between the biogas and traditional systems. The payback periods, cumulated life-cycle savings and the cost of biogas are calculated for a wide range using two unstable economic parameters, discount and inflation rates. The quality of the model and the assumptions are discussed. The results provide evidence of the economic viability of biogas systems over the traditional space heating systems of rural Turkey in many instances [9,33].

Turkey is one of the countries with significant potential in geothermal energy (at present seventh in the world) and there may exist about 2000 MWe of geothermal energy usable for electrical power generation in high enthalpy zones. Turkey's total geothermal heating capacity is about 31,500 MWth. At present, heating capacity in the country runs at 1220 MWth equivalent to 147.000 households. These numbers can be heightened some seven-fold to 6880 MWth equal to 585.000 households through a proven and exhaustible potential in 2010. Turkey must target 1.2 million households equivalent 7700 MWth in 2020 [41–43].

The yearly average solar radiation is 3.6 kWh/m^2 – day and the total yearly radiation period is approximately 2640 h, which is sufficient to provide adequate energy for solar thermal applications. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions [43]. In 2006, country has about total 7.0 million m^2 solar collectors and it is predicted that total energy production is about 0.390 Mtoe in 2006. Although solar energy is the most important renewable energy source it has not yet become widely commercial even in nations with high solar potential such as Turkey [44]. The energy consumption for heating and cooling of buildings in Turkey was about 23 Mtoe for the year 2006 [33]. The average household in Turkey needs more that 60% of its total energy consumption for space heating. The cooling demand in buildings increased rapidly in south region of the country at the summer season. The reason, besides general climatic and architectural boundary conditions, is an increase in the internal cooling load and higher comfort requirements [29,33].

There are a number of cities in Turkey with relatively high wind speeds. These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000 and 3000 kWh/(m^2 yr). The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland. Turkey's first wind farm was commissioned in 1998, and has a capacity of 1.5 MW. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2008, total installed wind energy capacity of Turkey is only 200 MW. Electrical power resources survey and development administration (EIE) carries out wind measurements at various locations to evaluate wind energy potential over the country, and have started to compile a wing energy atlas [44].

7. Water resources for hydropower in Turkey

In Turkey, renewables represent about 12% of TPES. More than half of the renewables used in Turkey are combustible fuels and waste, the rest being mainly hydro, solar and geothermal. Turkey is richly endowed with hydropower, wind and geothermal resources. Sectoral studies have indicated that small-scale hydropower (less than 20 MW) is underdeveloped, with 90 plants in operation compared with 350 prospective development sites and a total potential production of 33 TWh of electricity per year (about 25% of current demand) [9,25,43].

There is also large potential for geothermal and solar thermal applications in Turkey. Solar collectors are already a significant, market-driven business. The government expects the use of geothermal and solar energy to double between 2007 and 2020. The Geothermal Energy Law, enacted in 2007, aims to boost geothermal residential heating. The organic component of waste incineration is also considered a renewable option in the future, using appropriate technology to meet high health and environmental standards. On the other hand, commercial use of renewable energy has not developed rapidly. Financial assistance is being provided for the development of renewable energy projects. In 2004, USD 200 million was made available; by 2008, about half had already been committed to finance 19 projects with several other projects under preparation [24,27].

In 2005, primary energy production and consumption has reached 28 and 94.3 million tons of oil equivalents (Mtoe) respectively (see Table 3). The most significant developments in production are observed in coal production, hydropower, geothermal, and solar energy.

Turkey's use of hydropower, geothermal and solar thermal energy has increased since 1990. However, the total share of renewable energy sources in TPES has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced that it will reopen its nuclear programme in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports [3,20,21,24,45].

Conventional electricity supply options include thermal (coal, oil, and gas), nuclear and hydropower. These technologies currently dominate global electricity generation (thermal 60%, hydraulic 20%, nuclear 17% and all others 3%, approximately). Use of cogeneration, particularly geothermal and wind generation, both for isolated supply and small-to medium-scale grid-feeding applications, is small but increasing globally [3,6,46–48].

The generation of hydropower provides an alternative to burning fossil fuels or nuclear power, which allows for the power demand to be met without producing heated water, air emissions, ash, or radioactive waste. Of the two alternatives to hydropower, in the last decade, much attention has been given to thermal power production because of the adverse effect of CO_2 emissions. With the increasing threat of greenhouse gases originating from such anthropogenic activities on the climate, it was decided to take action. Thus the FCCC was enacted on 21 March 1994 and has been signed by 174 countries to date [3,6,45].

Dams that produce electricity by this most productive renewable clean energy source in the world provide an important contribution to the reduction of air pollution. The result of an investigation held in the USA suggests that the productivity of hydroelectric power-plants is higher than 90% of thermal plants and this figure is twice that of thermal plants. In case of Turkey, the public has been wrongly informed. Some people have claimed that hydro plants do not produce as much energy as planned because of irregular hydrological conditions and rapid sedimentation of reservoirs. It is also claimed that the cost of the removal of dams entirely filled by sediment at the end of their physical lives is not considered in the total project cost, and that there are major problems in recovering the cost of investment and environmental issues [3,6,45,49].

Hydropower generation climbed from 2 Mtoe (23.1 TWh) in 1990 to 3.0 Mtoe (35.3 TWh) in 2004, growing on average by 3.8% per year. The economic hydropower potential has been estimated at 128 TWh per year, of which 35% has been exploited. The government has a strategy for developing the hydropower potential and expects a few hundred plants to be constructed over the long term adding more than 19 GW of capacity. Construction costs would be approximately US$ 30 billion. The government expects hydropower capacity to reach about 31,000 MW in 2020. Some 500 projects (with a total installed capacity over 20,400 MW), which are

in different phases of the project cycle, are awaiting realization. On the other hand, Turkey has a lot of potential for small hydropower (<10 MW), particularly in the eastern part of the country. At present the total installed capacity of small hydropower is 176 MW in 70 locations, with annual generation of 260 GWh. Ten units are under construction with a total installed capacity of 53 MW and estimated annual production of 133 GWh. Furthermore, 210 projects are under planning with a total capacity of 844 MW and annual production of about 3.6 TWh [3,6,50].

8. Water development for sustainable energy future in Turkey

Water resources development around the world has taken many different forms and directions since the dawn of civilization. Humans have long sought ways of capturing, storing, cleaning, and redirecting freshwater resources in efforts to reduce their vulnerability to irregular river flows and unpredictable rainfall. Early agricultural civilizations formed in regions where rainfall and runoff could be easily and reliably tapped. The first irrigation canals permitted farmers to grow crops in drier and drier regions and permitted longer growing seasons. The growth of cities required advances in the sciences of civil engineering and hydrology as water supplies had to be brought from increasingly distant sources [51–54].

It is very important to project the energy demand accurately, because decisions involving huge investments of capital are based on these forecasts. Turkish Electricity Transmission Company (TEIAS), has prepared the Long-Term Energy Generation Plan, taking into consideration model of analysis energy demand (MAED). According to the Plan, the installed capacity will increase to 57,551 MW in 2010 and to 117,240 MW in 2020. The installed hydropower capacity is anticipated to increase to 18,943 MW in 2010 and to 34,092 MW in 2020. Thus, an additional 1000 MW of hydro capacity should be added to the system annually over the next 20 years. Turkey is thus seeking support for the development of all its economic potential by 2023, which is the 100th anniversary of the foundation of the Turkish Republic [35,55–57].

Although Turkey has an adequate amount of water in general, it is not always in the right place at the right time to meet present and anticipated needs. As regards hydrology, Turkey is divided into 26 drainage basins. The rivers in general have irregular regimes, and natural flows cannot be taken directly as usable resources. The average annual precipitation, evaporation and surface runoff geographically vary greatly [58–60]. On the other hand, Turkey has 665,000 ha of inland waters, excluding rivers and small streams. There are 200 natural lakes, with a total area of 500,000 ha, and 775 dam lakes and ponds with a total surface area of 165,000 ha [58].

With the projects developed primarily by state water works (DSI) and other institutions engaged in water resources development, water consumption in Turkey reached 39.3 billion m^3 by 2000, corresponding to only 36% of the economically exploitable water resources. During water consumption estimates on a sectoral basis, it is accepted that all of the economically irrigable land will be irrigated with irrigation schemes constructed by the year 2030 and water consumption for irrigation will be 71.5 billion m^3. Hence, while its share in the total consumption was 75% in 1999, the share of irrigation water in the total water consumption will be decreased to 65% by the year 2030, through the utilization of modern irrigation techniques [60,61].

It has been accepted that the total population of Turkey will reach 110 million by 2030, with an annual increase rate of 2%. Additionally, it is assumed that the per capita water consumption of 280 l/day (in 2003) will reach 540 l/day by 2030. By taking into consideration that about 5.2 billion m^3 water is needed in the tourism sector, the total water consumption for domestic purposes will reach 26.1 billion m^3 by 2030. With the assumption of 4% annual growth rate in the industrial sector, it is expected that industrial water consumption will increase from 4.8 billion m^3 in 2003 to 13.2 billion m^3 in 2030. Thus, considering all of these issues that 100% of the total economically exploitable water resources will be under use by the year 2030 [58–60].

9. Energy policy for sustainable energy in Turkey

The basic principle of Turkish energy policy, as set out in the 9th National Development Plan (2007–2013), was to ensure sufficient energy supply to meet the increasing demand, at the lowest cost possible. The 9th plan also introduced provisions for minimising negative environmental impacts, improving energy efficiency and increasing the share of renewable energy in energy consumption [24]. Some investments have already been made, especially to address the environmental impacts of the high sulphur content of domestic lignite. New lignitefired power plants have been equipped with flue gas desulfurization (FGD) technology to comply with regulations. Six of eleven pre-1986 lignite-fired plants have been retrofitted with electrostatic precipitators (ESP) to reduce particulate emissions. However, not all electrostatic precipitators are working at maximum efficiency. Construction of one power plant based on circulating fluidised bed technology has recently been completed [9,25,28]. This first application of advanced coal technology in Turkey, designed to use low-quality lignite with high sulphur content, was followed by other plants. Studies on compliance with European Union (EU) Large Combustion Plants (LCP) Directive indicate that an investment of over USD 1 billion would be needed to retrofit installed FGD and ESP facilities and to adopt advanced coal technologies [20,28].

Energy intensity decreased by 8% between 1990 and 2005 and is below the OECD average. Its improvement through improved sectoral energy efficiencies is an important objective of Turkey, which should bring multiple benefits: economic benefits, environmental benefits and related health benefits. Official studies have demonstrated that Turkey has large energy conservation potential (25–30%). Energy efficiency policies have been implemented in the industrial, residential and services sectors. General investment support programmes also have an indirect positive impact on energy efficiency. There are no direct tax incentives to encourage end-use energy efficiency, nor is there any other kind of direct financial incentives.

On the other hand, the National Energy Conservation Centre (EIE/NECC) has provided training to consumers on energy conservation measures, conducted energy audits in industry, maintained energy consumption statistics for the industrial sector and public buildings, and co-ordinated dialogue and co-operation with the relevant institutions. In the last ten years, the Energy Efficiency Strategy was adopted to support, in a more comprehensive way, energy efficiency in the final energy consumption sectors and more actively engage ministries and stakeholders in applying energy efficiency measures [27].

The preceding discussion already has laid the foundations for an analytical framework necessary to understand the structural dynamics and political forces at work. The discussion of the determinants of energy intensity and energy sources makes it clear that specific policy outcomes can be understood as a function of two conceptual categories concerning policy-making: regulation and technology. While these two conceptual categories account for most aspects of environmental and energy policy outcomes, a third indicator, political outlook, is required to fully capture the domestic and geopolitical forces at work in Turkey [3].

The first category, regulation, concerns both the means of devising regulatory frameworks on energy and the overarching goal of such policies. The second category also comprises two variables: the relationship between technology and risk and the nature of technology implementation. Finally, the category of political outlook comprises a discursive alignment and outlook on the nature of international relations [3,9,10,20,21]. Using these three categories, it is possible to construct a matrix of the competing energy and environment discourses in Turkey. For the sake of simplicity, only two major orientations though a variety of combinations are possible. These do not necessarily correspond with real world actors as the matrix is merely intended as a heuristic device to chart the profile of the ongoing policy debates in Turkey. Naturally, the real world of energy politics has various shades of gray, and it is not uncommon for actors to borrow from each camp over time. Nevertheless, these two positions, Greens and Develop mentalists, capture the tenor of the ongoing debate in Turkey [3,10,62].

Greens believe in extensive environmental regulation. In line with their European and North American counterparts, Greens in Turkey articulate their positions with an implicit critique of markets that question both their desirability as social institutions and effectiveness as regulatory tools. Thus, this position is characterized by calls for the direct involvement of the state in protecting the environment through command-and-control mechanisms. Moreover, Greens privilege ecological protection over continued economic growth. This is not to suggest that this position rejects economic growth entirely, since such deep ecology-inspired movements in Turkey remain relatively rare. The practical upshot of this for their energy policy is built around small-scale and alternative technologies, such as wind farms and solar panels. Finally, in their political outlook, the Greens in Turkey parallel the 'liberal' school of international relations, constructing their discourse around concepts such as multiculturalism and universal human rights, believing on the one hand that non-state actors are increasingly important in energy politics and on the other interpreting the interstate system as one characterized by win–win cooperation [3,10,62].

The emissions standards for power plants remain significantly less stringent than those currently in force at the European Union (EU) level as defined by the revised Large Combustion Plants (LCP) Directive. For example, for new solid fuel-fired power plants with a thermal input greater than 300 MW, the NOx emissions limit is set at 200 mg/Nm^3 at the EU level, while the NO_x emissions limit is 800 mg/Nm^3 in Turkey. On the other hand, first estimates show that achieving the standards defined under the LCP directive would entail investments of over US$ 1 billion. This would include investments in the retrofitting of installed FGD and ESP equipment and the adoption of advanced and environment-friendly coal technologies [3].

"Air Pollution Control Regulation", especially in industry is an important step towards aligning air quality standards with EU regulations, but more efforts will be needed [3,6,20,25]. Construction of one power plant based on circulating fluidized bed technology has recently been completed. The plant is the first application of advanced coal technology in Turkey and has been designed to use low-quality lignite with high sulfur content. The industry and residential sectors are also responsible for significant air pollution, mainly as a result of lignite consumption. In order to reduce emissions from these sectors, the state-owned Turkish Coal Enterprises (TKI) has developed significant lignite washing capacity. By the end of 2006, total washing capacity was approximately 10.8 Mt, equivalent to current coal demand from both sectors. In addition, the use of high-sulfur coal in residential heating is prohibited. Lastly, the substitution of gas as distribution networks are expanded in urban areas should further contribute to reduce air pollution [3,6,20,21,63].

10. Conclusion

Energy access for all will require making available basic and affordable energy services using a range of energy resources and innovative conversion technologies while minimizing GHG emissions, adverse effects on human health, and other local and regional environmental impacts in the country. To accomplish this would require governments, the global energy industry and society as a whole to collaborate on an unprecedented scale. The method used to achieve optimum integration of energy sustainability with more efficient energy systems should be made. Wide range of energy sources and carriers that provide energy services as a sustainable manner need to offer long-term security of supply, be affordable and have minimal impact on the environment.

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources such as solar and wind. Turkey has substantial reserves of renewable energy sources, including approximately 1% of the total world hydropower potential. There is also significant potential for wind power development. Turkey's geothermal potential ranks seventh worldwide, but only a small portion is considered to be economically feasible. On the other hand, renewable energy sources exception of large hydro are widely dispersed compared with fossil fuels, which are concentrated at individual locations and require distribution. Hence, renewable energy must either be used in a distributed manner or concentrated to meet the higher energy demands of cities and industries.

Turkey has made significant progress in reducing local air pollution, particularly in large cities. Nevertheless, significant efforts still need to be made to ensure existing standards are met and to prepare for further reductions in air pollution. The potential long-term impacts of the liberalization process on air pollution and on GHG emissions should be investigated and monitored in order to optimize policy outcomes. The recent construction of a power plant based on fluidized bed combustion technology is laudable. Further adoption of such cleaner coal plants and more efficient technologies would help Turkey meet more stringent air pollution standards. Similar to other industrializing countries, with the increases in energy consumption and economical growth, energy related environmental problems are rapidly growing in Turkey.

Turkey's high rate of energy-related carbon emissions growth is expected to accelerate, with emissions climbing from 57 million tons in 2000 to almost 210 million tons in 2020. Carbon intensity in Turkey is higher than the western developed nation average. For example, Turkey's total CO_2 emissions amounted to 297 million tons (Mt) in 2008. Energy-intensive, inefficient industries remain under government control with soft budged constraints, contributing to undisciplined energy use in Turkey.

Hydropower represents an alternative to fossil fuel generation, and does not contribute to either greenhouse gas emissions or other atmospheric pollutants. However, developing the remaining hydropower potential offers many challenges and pressures from some environmental action groups over its impact has tended to increase over time. Moreover, in the context of the restructuring of the electricity sector, markets may favor more polluting and less costly options. On the other hand, small hydropower's main challenges relate to both economics and ecology. Especially small hydropower can be successfully developed as long as it produces electricity at competitive prices and under conditions that respect the environment. In addition, hydro plants are often superior to other power plants from the standpoint of socio-economic and environmental considerations. The environmental impacts of

hydropower plants are at the lowest level compared with the other alternative resources for renewable and sustainable energy [3].

The other conclusions have been drawn from this paper as follows:

- Developing countries are likely the most vulnerable to this change because of their less favorable economic circumstances, weaker institutions and more restricted access to capital, technology and information.
- Given rapid growth of economies and populations, there are a number of implications for developing countries that indicate a need to curb GHGs and thereby to lessen the impact of climate change.
- Great efforts have been made in reforming energy pricing, promoting energy efficiency and the use of renewable energy sources.
- Turkey's high rate of energy-related carbon emissions growth is expected to accelerate, with emissions climbing from 57 million tons in 2000 to almost 210 million tons in 2020.
- Carbon intensity in Turkey is higher than the western developed nation average.
- Energy-intensive, inefficient industries remain under government control with soft budged constraints, contributing to undisciplined energy use in Turkey.
- The reduction of emissions can only be achieved when policies are supportive and well targeted, standards and incentives are realistic and flexible, and the public is actively responsive to environmental degradation.

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